Modeling Fireside Slag Formation and Deposition in Tangentially-Coal-Fired Boilers

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Introduction
Fireside ash deposition is a major problem that impacts the efficiency and operability of coal-fired utility boiler. The ash deposition problem is dependent on fuel composition, boiler design, and operating conditions. In general many of the chemical and physical processes involved in ash formation and deposition are understood and this understanding has assisted many utilities in minimizing ash deposition problems in utility boilers. Many of these processes have been formulated into computer codes. For example, computer codes exist to predict the particle-size and composition distribution (PSCD) of the ash produced upon combustion (1) and simplified transport deposition and growth programs for specific locations in the boiler (2). However, no integration of these programs with boiler models to predict the effects of deposit growth on heat transfer has occurred.

The advances made over the past several years in predicting ash behavior have been made possible as a result of more detailed and better analysis of coal and ash materials. These advanced techniques, such as computer-controlled scanning electron microscopy (CCSEM), are able to quantitatively determine the chemical and physical characteristics of the inorganic components in coal and ash (fly ash and deposits) on a microscopic scale (3). Many of the mechanisms of ash formation, ash deposition, and ash collection in combustion systems are more clearly understood as a result of these new data. This understanding has led to the development of better methods of prediction that include advanced indices and phenomenological models.

Advanced indices programs provide coal ranking with respect to a coals potential to cause deposition in various sections of the boiler such as the waterwalls and high-temperature and low- temperature convective pass. The index is based on advanced methods of analysis, detailed understanding of key processes that influence fouling, and full-scale performance data (4).

Phenomenological or mechanistic models have been developed and are being used to predict the effects of ash-forming constituents as a function of coal composition, combustion conditions, systems geometry, and operating conditions. ATRAN is a model that has been developed to predict the PSCD of ash produced in utility boilers. The results achieved with this model have been verified with full-scale experience for both pulverized coal (pc) and cyclone-fired boilers with a favorable outcome. ATRAN is a vital part of other methods used to predict the effects of ash species, since the PSCD is needed to predict ash deposition (5).

Recently work has been conducted to integrate the predictive methods and incorporate them into a computational fluid dynamics code. The results presented here will illustrate the ability of the model to predict upper wall slagging in a tangentially fired boiler utilizing. Black Thunder, a Powder River Basin coal.

Computational Fluid Dynamics
SmartBurn® uses numerical simulations of processes to compare design and operational alternatives and to identify the underlying limitations of boiler performance. Once these limitations are identified, a cause and effect relationship can be established and a more complete understanding of the combustion process is obtained. The tool of choice for performing such an investigation for pulverized coal combustion in an enclosed fluid atmosphere is computational fluid dynamics (CFD). This type of numerical simulation resolves the Navier-Stokes equations and incorporates several numerical schemes for fluid flow, heat transfer, turbulence, and chemistry within the given geometry and for a set of operating conditions and, most importantly, solves the coupled solution of these equations.

Coal particles are simulated with the Discrete Phase Model (DPM) in a two way coupled solution utilizing stochastic tracking for turbulence interaction in a Lagrangian reference frame. The DPM model is defined to simulate the moisture evaporation, de-volatilization, and char burnout of the coal particles. Seven chemical species are solved for the gas phase in which the Magnussen-Hjertajer turbulence-chemistry interaction model is employed. Radiation is modeled using the Discrete Ordinate (DO) model, which provides for particle radiation interaction.

A CFD model was built for Columbia Unit 1 (6,7) a tangentially fired 1975-vintage 512 MW boiler. Columbia Unit 1 was one of the first-generation T-fired units designed to burn PRB coal and therefore has a small firebox with a high heat release. The output of the CFD model provides the basic information used in the ash behavior model.

Results and Discussion
A diagram of the boiler modeled is illustrated in Figure 1 (7). The portion of the boiler that will be used to illustrate the ability of the model to predict performance is the upper wall section above the burner level. The ash impaction rates are shown in Figure 2.

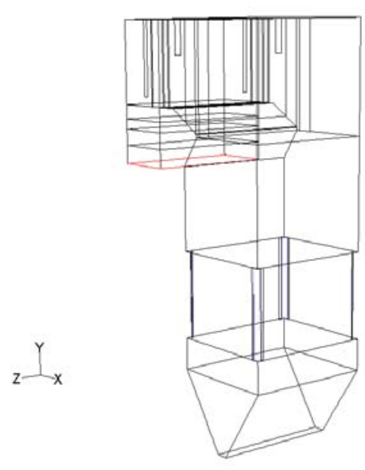

Figure 1. Schematic diagram of tangentially-fired boiler.

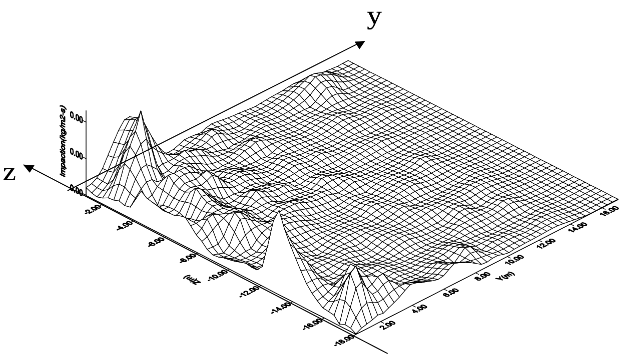

Figure 2. Ash Particle Impaction Rate Distribution on Furnace Upper-Front Wall

Currently work is being conducted to validate the model. Figure 3 shows the heat flux measurements made at several locations on the upper wall panel that is being modeled. Figure 4 shows the results from the model.

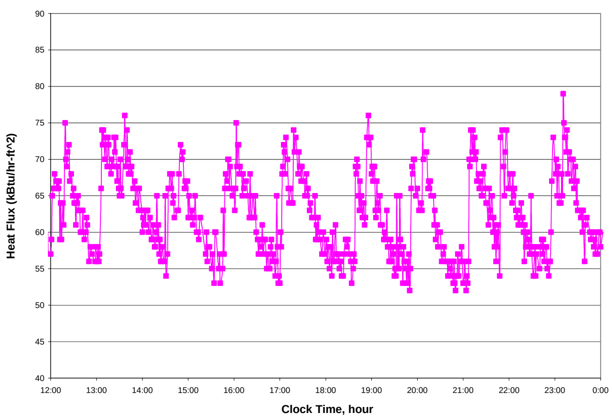

Figure 3. Measured Heat flux at the full scale utility on the wall panel is illustrated in Figure 2.

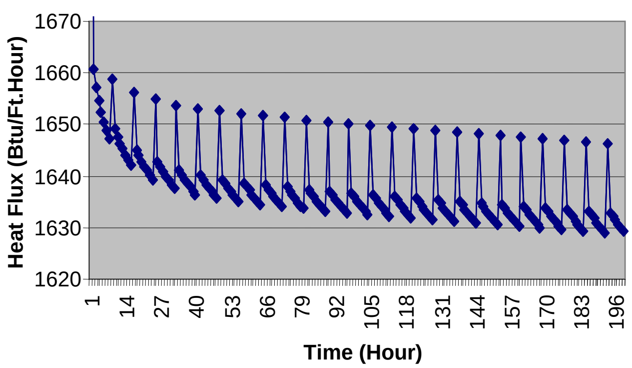

Figure 4. Predicted heat flux based on fuel quality, boiler design, and operating conditions.

Currently the modeling efforts show promise in being a very valuable tool to predict plant performance.

Conclusions

The resulting integration of CFD simulations with predictive methods for ash behavior in tangentially coal-fired boilers, provide a quantitative and qualitative description of the fireside slag formation and deposition processes within the furnace. As a result, the method permits the determination of the deposit thickness; chemical composition; physical properties and heat transfer properties. The utilization of this procedure to different types of boilers, fuel types and operating conditions is in progress.

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